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A Commercial Off The Shelf (COTS) Based Military Telemedicine System

G.S. Harrison

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A Commercial Off The Shelf (COTS) Based Military Telemedicine System

G.S. Harrison

Communications Division
Electronics and Surveillance Research Laboratory

DSTO-TR-0512

ABSTRACT

An experimental Commercial Off The Shelf (COTS) based telemedicine system was developed in less than three months and trialed on HMAS Success during RIMPAC '96. It provided similar functionality to commercial telemedicine systems, but at reduced cost. It increased both the level of support to ship's medical staff and medical care to ship's crew, but to derive maximum benefit the technology needs to be supported by doctrine and organisation structure.

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Executive Summary

Telemedicine is the application of information technology and telecommunications to the delivery of remote medical support. In a military context, telemedicine can enhance the life saving effectiveness of deployed medical units by providing real-time, remote access to specialty-trained physicians and medical information databases. The expertise and support of medical centres is electronically projected forward to assist deployed staff. Telemedicine also reduces transportation of military personnel for routine medical care and generally has a positive influence on the utilisation of evacuation assets.

Telemedicine is significantly deployed in the US military and is a growth area providing capabilities such as: full motion video teleconsultation; remote specialty surgery mentoring; teleradiology; telepsychiatry; remote access to patient records clinical email, and medical situational awareness.

The Australian Defence Force (ADF) has had no major involvement in fielding telemedicine facilities and the RIMPAC '96 telemedicine trial was the first deployment of a telemedical capability.

The Defence Science and Technology Organisation (DSTO) Project Pilgrim—a wideband communications network technology demonstrator - provided an opportunity to develop and demonstrate military telemedical technology for the Surgeon General ADF during RIMPAC '96. Pilgrim was extended to a mobile naval platform via a commercial satellite.

The telemedicine trial had the following objectives:

1. to demonstrate the feasibility of telemedicine in an Australian naval environment ,
2. to identify potential future requirements for military telemedicine systems,
3. to utilise commercial-off-the-shelf (COTS) technologies in telemedicine ,
4. to illustrate a potential application for wideband military networks.

Since the Pilgrim telemedicine network was isolated from civil telemedicine systems its ability to electronically transfer information with such systems was not trialed.

Telemedical capabilities demonstrated in the trial were: telemedical and welfare video conferencing; teleradiology; telepathology; telecardiology; and medical training.

The trial of telemedical support to a naval ship at sea in peace time was successful, increasing the level of support to the medical staff and enhancing the level of medical care available to the ship's crew. The quality of medical information transmitted from the ship was satisfactory for shore-side diagnosis and it was shown that low cost COTS digital enhancement techniques can assist with analysing medical imagery. The

welfare video conferencing was well received by participants and significantly boosted morale.

The trial provided valuable data for future requirements of military telemedicine systems. To obtain maximum benefit from telemedicine, a system needs to be matched with work procedures and the organisational structure. This was not the case in this initial trial.

The telemedicine system was developed in-house by DSTO and evolved from concept to deployment in approximately three months with the use of commonly available COTS technologies. It provided similar functionality to commercial telemedicine systems but at reduced cost. COTS products also had the benefits of minimising user training and allowing minimal spares to be carried.

A disadvantage of COTS was that some products used offered less functionality than the full price commercial alternative. COTS products experienced only minor problems in the naval electromagnetic environment which trial did not address. The equipment was not optimised for physical space and although fitting in the sick bay of HMAS Success with some cramping, it would not have fitted into a DDG or FFG sick bay.

Author

G.S. Harrison
Information Technology Division

Garry Harrison is an Electronic Engineer in Network Integration Group, DSTO Fernhill Park, Canberra. He graduated in 1991 with first class honours Bachelor degree in Electrical Engineering from the University of Sydney. Gary also has a Bachelor degree in Science, with majors in mathematics and computer science, from the University of Sydney. He has worked on the development of prototype command support systems and the establishment of a research ATM network node at DSTO Canberra. Recent work has involved the development and trial of a telemedicine system for the Australian military.

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Telemedicine is the application of information technology and telecommunications to the delivery of remote medical support. In a military context, telemedicine can enhance the life saving effectiveness of deployed medical units by providing real-time, remote access to specialty-trained physicians and medical information databases. The expertise and support of medical centres is electronically projected forward to assist deployed staff.

The biggest potential savings from telemedicine is in lives saved through enhanced medical care on the front line of military action. It further saves money by reducing the need to evacuate military personnel for routine medical care and generally has a positive influence on the utilisation of evacuation assets.

Telemedicine is a growth area in the US military which has realised benefits in the above areas Ref[1][2]. There are significant deployments of telemedical units within the US military forces utilising capabilities which include: remote access to patient records; full motion video teleconsultation; remote specialty surgery mentoring; teleradiology; telepsychiatry; clinical email, and medical situational awareness Ref[3].

The Australian Defence Force (ADF) has had no major involvement in fielding telemedicine facilities and the RIMPAC '96 telemedicine trial was the first deployment of a telemedical capability.

Defence Science and Technology Organisation (DSTO) Project Pilgrim was a technology demonstrator aiming to extend wideband asynchronous transfer mode (ATM) technology to a mobile naval platform using commercial C-band satellite. It was developed to help define user requirements for future Command, Control and Communications (C3) systems for the ADF. Although telemedicine was not a mainstream application within Pilgrim, RIMPAC '96 provided an opportunity for DSTO to develop and demonstrate military telemedical technology for the Surgeon General ADF.

The development of the telemedicine system and its deployment in RIMPAC '96 had the following objectives:

1. to demonstrate the feasibility of telemedicine in an Australian naval environment ,
2. to help identify future requirements for military telemedicine systems,
3. to gain maximum leverage from the use of commercial-off-the-shelf (COTS) technologies,
4. to illustrate a potential application for wideband military networks.

The telemedicine system was developed in-house by DSTO and evolved from concept to deployment in approximately three months with the use of COTS technologies.

2. Aim

The aim of this report is to document the development of a COTS based military telemedicine system and make recommendations for further investigations.

3. Scope

This report covers the technical support provided by DSTO to the telemedicine trial conducted during RIMPAC '96. It encompasses system preparation, development and conduct of the trial. It addresses issues relating to the technical feasibility and required capabilities of a military COTS based telemedicine system.

The following are not within the scope of this study:

1. the requirements or capabilities of the underlying Pilgrim communications network,
2. wartime communication constraints that may be placed on telemedicine activities,
3. the detailed costs of the telemedicine system, network or trial,
4. potential impacts of using a single communication network for both C3 and telemedicine as covered by international war-fighting conventions,
5. the relevance or impact of the results of the trial on military medical effectiveness.

4. Background

4.1 Trial Plan

A trial plan was developed by the collaboration of the Surgeon General's office, Maritime Headquarters (MHQ), Naval medical staff and DSTO. The plan was broadly divided into three parts:

1. the exchange of sets of medical control samples from the ship to shore based facilities to assess the quality of the transmitted information,
2. a series of medical scenarios covering a range of treatments appropriate to the trial,
3. and any real medical situations/emergencies or other service requirements which arose during the trial period.

4.1.1 Medical Control Samples

Control samples were utilised to assess the likelihood of accurate diagnoses being made on received information which could be degraded by the telemedicine digitisation, transmission and display processes. Ten x-ray samples, ten pathology samples and ten electrocardiogram (ECG) samples were to be used.

4.1.2 Medical Scenarios

The scenarios simulated activities that occur when a patient is treated. They tested the interaction between the medical staff and the telemedicine equipment, and collaboration between ship and shore medical staff. They allowed an assessment of the usability of the equipment and an evaluation of procedural issues. The scenarios utilised the medical control samples as a source of data.

4.1.3 Real Medical Situations and Other Services

The telemedicine system was to support any real medical situations or emergencies and any other medically related services such as welfare video conferencing which occurred during trial and which could make use of the system.

4.2 Preparation

Technologies, standards and equipment for digitising, storing and viewing radiographic information were examined by the trial staff during a visit to the filmless digital radiology unit at Westmead New Children's Hospital. Insight was also gained into user and software interfaces of the system and the capacity of the underlying network. Appendix E details technical information obtained.

Other activities included a study of commercially available telemedicine systems and close consultation with the medical staff of HMAS Success and HMAS Penguin to assess their familiarity with the technology and the level of training required.

In performing a diagnosis from a digital image special consideration of image quality and an understanding of the benefits of image enhancement is required. To support and train the medical staff on image utilisation during the trial, and to ensure full benefits of the technology were obtained, DSTO staff participated in a one day workshop on Adobe PhotoShop and its application to telemedicine.

A telemedicine testbed was set up at DSTO Fern Hill to develop and test the system prior to its deployment in RIMPAC '96.

5. The Telemedicine System

5.1 System Description

The telemedicine network was made up of two nodes, one at HMAS Penguin in Sydney and the other on HMAS Success participating in the RIMPAC '96 exercise near Hawaii. These nodes were connected over the Pilgrim technology demonstrator which is detailed in Appendix A. This network permitted video conferencing as well as transmission of electronic mail, patient records and medical images.

Network facilities at HMAS Penguin were provided by a transportable Pilgrim node. A small truck containing the equipment, and towing a 2.4m satellite dish, was driven to HMAS Penguin where no previous infrastructure existed. The transportable node was deployed and the system brought online within half a day. The telemedicine equipment was located in the outpatients treatment room at Balmoral Naval Hospital and connected to the Pilgrim truck and network.

On HMAS Success all telemedicine equipment was located in the sickbay and doctor's office. Network equipment such as the Sun workstation and ATM switch were located in the communications centre (COMMCEN).

The design of the telemedicine system was based on maximising the use of COTS equipment and open civil standards. The hardware was based on personal computers (PCs) with some medical specific peripherals such as microscope, x-ray scanner and ECG machine. The software was based on common COTS applications such as Microsoft Windows for Workgroups, Netscape Navigator and Adobe PhotoShop. These were combined with specialist (e.g. x-ray scanner) software for an integrated suite of telemedicine applications.

Telemedical capabilities were provided by video conferencing, still image capture and transmission, electronic mail, and file transfer capabilities. Video conferencing was utilised for consultations, collaboration between medical staff, staff training through remote presentations, and welfare conferencing. Still image transmission was utilised for x-rays, ECGs, pathology slides, and images of patients' external injuries. Electronic mail provided the exchange of medical records.

5.2 Satellite Bearer

Communication between HMAS Success and HMAS Penguin was via commercial satellites. A double satellite hop was used in which data was transmitted from HMAS Penguin to DSTO Salisbury, and then relayed via a second satellite to HMAS Success. The satellite links provided coverage of Australia and Hawaii and its territorial waters. Details are in Appendix A.

5.3 Hardware

The telemedicine system hardware deployed on HMAS Success is depicted in Figure 5.1. A PC was used to control the telemedicine system (excluding the video conferencing subsystem). It provided a platform for the telemedical software as well as standardised small computer systems interface (SCSI) and serial connections to the peripheral devices. A Sun workstation in the Pilgrim network provided internet protocol (IP) routing for local area network (LAN) interconnection between telemedicine nodes. The video conferencing subsystem was controlled from the video codec.

The telemedicine system hardware at HMAS Penguin (not shown) was the same as at HMAS Success, with the exceptions that peripheral equipment for image digitisation was excluded and a larger monitor was included (for making diagnoses from images).

The PC was connected to: a x-ray scanner; an electrocardiograph machine; a flatbed scanner; a digital camera; and a high resolution monitor. A laser printer was available for producing hard copy.

The Raven x-ray scanner was a specialised digitiser capable of scanning x-ray films up to full chest size. The scanning process produced an image file on the hard disk of the PC.

The CT200 ECG machine captured a 12 lead, 7 second snapshot of a patient's heart functioning which was downloaded to the hard disk of the PC. This unit performed well in the high electromagnetic interference (EMI) environment of HMAS Success.

The flatbed scanner was used for digitising general hardcopy information, such as ECG printouts, which were saved to the hard disk of the PC.

The Kodak DCS200 digital camera (when attached to the microscope) captured an image of the area of a pathology slide under observation. The camera was also used to capture images of skin disorders in patients. Camera output was downloaded to the hard disk of the PC.

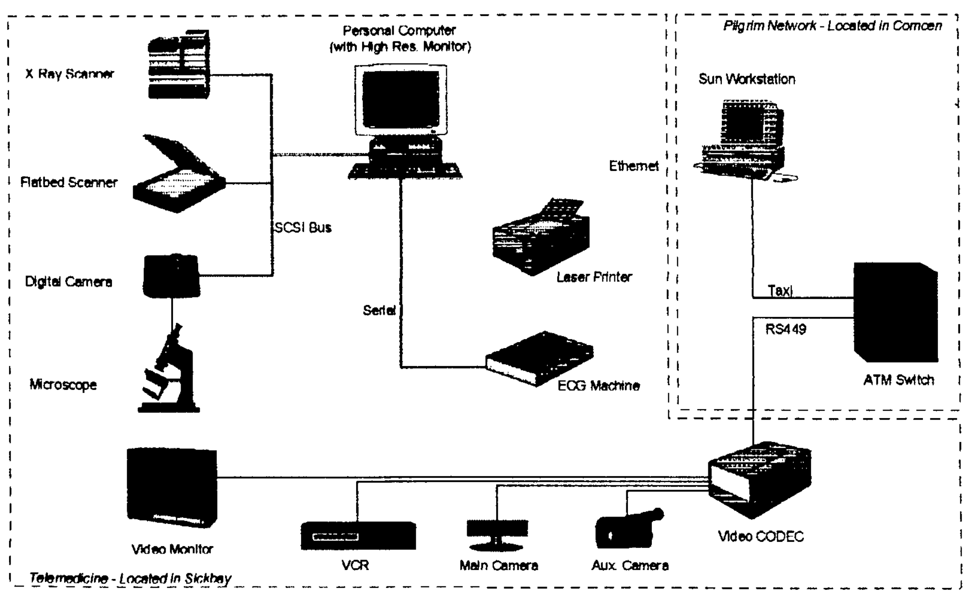

Figure 5.1 *Telemedicine hardware on HMAS Success*

The telemedicine video conferencing subsystems at both HMAS Success and HMAS Penguin consisted of: a video coder/decoder (codec); a main camera; a separate video monitor; a video cassette recorder (VCR); and an auxiliary video camera (HMAS Success only). The video codecs were connected directly to the ATM switch of the Pilgrim network.

Appendix B details the hardware including the rationale for its selection.

5.4 Software

The telemedicine software consists of a suite of applications for acquiring, viewing and manipulating digital images, and for sharing images and ancillary information with remote sites via email. The telemedicine system software is detailed in Appendix C.

Microsoft Windows for Workgroups was the chosen operating system upon which the telemedicine software was developed. This provided a familiar, easy to use interface for the medical staff and minimised the training requirements during the trial. A wide range of COTS software was available for this operating system.

Netscape Navigator, a web browser, was used for its information distribution capabilities and as an email tool. Using Netscape, the digital image and data files created with the telemedicine equipment could be easily attached to an email and sent to the remote node. It also provided a filing system where reports and images could be kept in an organised fashion for later retrieval and viewing. Netscape was also a useful tool for integrating other applications, such as PhotoShop, into a single user interface. For example, when an email was received with an x-ray attached, Netscape would start PhotoShop to view the image.

Adobe PhotoShop was a significant part of the telemedicine software because of its powerful image enhancement capabilities which were necessary for making a reliable medical diagnosis from digital imagery. Through the use of standard software drivers PhotoShop provided the connection to the software which controlled the flatbed scanner and DCS200 digital camera.

Specialist software was required to operate some of the medical equipment. This included the interface for the Raven scanner, which would scan an x-ray to a file on disk, and the software for the ECG machine, which would download an ECG file to disk.

Other software included the Microsoft Office suite for office automation, and file transfer protocol (FTP) for exchanging files between network nodes.

5.5 System Procedures

This section summarises the procedures undertaken to utilise the capabilities of the telemedicine system.

Relevant medical information was digitised using the appropriate telemedicine equipment and the resulting files were stored on the PC. The files were then attached to an email

message created in Netscape and transferred to HMAS Penguin over the Pilgrim network. Generally, for the control samples only the attached file of digitised information was sent, but for the scenarios and real cases the email included additional details such as the patient's history, any symptomatic information and a suspected diagnosis. The email also stated what service was required at the remote end.

The email was received by the remote node and the appropriate action was initiated to satisfy the requested service. For the control samples, only an analysis of the transferred data and a diagnostic service was required. The x-rays and pathology samples were diagnosed directly from the computer screen by visiting specialists. The ECGs were printed out and sent to a cardiologist by traditional mail for diagnosis. All results were communicated to the ship's doctor in a reply email. The results were also compared to reference diagnoses made from the original samples.

The scenarios and real medical situations required additional services, such as a remote consultation or collaboration with shore-based staff by video conference. The video conferencing facility was used throughout the trial to coordinate activities and allow liaison amongst the medical staff.

A more detailed description of the procedures as well as technical information on the digital image manipulation is given in Appendix D.

6. Results

6.1 Medical Control Samples

The control samples were digitised on HMAS Success, then transmitted to HMAS Penguin for diagnosis by naval medical staff and visiting specialists. In all cases the quality of the received information was considered of sufficiently high resolution and detail to make a reliable diagnosis possible.

6.1.1 X-Rays

A radiologist diagnosed ten out of the twelve x-rays correctly with high confidence, and the remaining two were diagnosed correctly but with reduced confidence. This was performed directly from the computer screen. The diagnostic effort was increased by the fact that no clinical history or symptomatic information was provided, and some "normal" (i.e. non-pathological) x-rays were included in the sample set.

6.1.2 Pathology Slides

A pathologist diagnosed all ten samples with high confidence directly from the computer screen. The diagnoses showed a good correspondence with the pre-trial reference diagnoses. Some clinical history was provided with each sample.

6.1.3 Electrocardiographs (ECGs)

A cardiologist diagnosed eleven samples with high confidence, showing an excellent correspondence to the pre-trial reference diagnoses. No symptomatic information was provided with the ECG samples. The quality of the ECG in electronic form was excellent and was considered superior to the digitised paper ECGs.

6.2 Medical Scenarios

The first of the scenarios was played out on 21st June 1996 with the rest being conducted on an ad hoc basis until 8th July. From a technical perspective the scenarios were a success with the activities of the medical staff being well supported by the telemedicine system. The staff were able to operate the equipment and interact with the system to address the issues of each scenario. The results from the scenarios showed a high correspondence with the expected diagnoses.

6.3 Real Situations/Emergencies

During the trial there were two notable real life medical situations in which the telemedicine system was utilised. Both involved skin disorders for which the ship's doctor sought a specialist's opinion to make a better decision regarding patient treatment. One case involved a video conference discussing a digital photograph of the affected area of a patient. The telemedicine system adequately supported both these situations.

6.4 Other Medical Services

Appointments with medical specialists were successfully made for crew members by the telemedicine system for when the ship returned to Sydney.

Welfare video conferencing proved successful being well received by participants and significantly boosted morale.

A medical training video was developed during the trial and relayed to the ship. The video was of reduced quality compared to normal television, due to video codec and Pilgrim bandwidth limitations, but was considered by the ship's doctor to be of acceptable quality.

7. Discussion

7.1 Suitability of COTS Products

The use of COTS hardware and software was found to be suitable for the development of a military telemedicine system and well supported the needs of the telemedicine trial. Through the use of commonly available COTS products a functionality similar to specialised medical systems was achieved but at a reduced cost. The hardware was widely

available, at short notice, allowing a repair by replacement scheme to be adopted and minimal spares carried. The system was rapidly developed from concept to deployment in less than three months.

The system was designed around open civil standards, including common image formats (JPEG, TIFF), communication protocols (TCP/IP, MIME), and hardware interfaces (SCSI, RS232). This increased the possibility of information exchange with other systems and interoperability with civilian telemedicine networks. However, at the time of the trial, no standard data format existed for the digital files produced by the CT 200 electrocardiograph machine. This may lead to future system incompatibilities restricting ECG exchange.

Some modification to the COTS products may however be necessary to meet the unique requirements of a military environment. On board HMAS Success limited space was available for mounting and locating the telemedicine equipment within the sickbay. As a result a less than optimum size computer screen was used and the x-ray scanner could not be conveniently located near the other equipment. Rack-mountable equipment was an advantage in this situation. Electromagnetic interference (EMI) produced by the harsh environment of HMAS Success affected the quality of images on the computer screen and adequate shielding may be necessary to protect the integrity of the computing equipment.

7.2 Quality of Telemedical Information

The quality of the medical imagery transferred between telemedicine nodes was considered good and of sufficiently high detail for a reliable diagnosis to be made. The level of detail in the x-rays and ECGs was comparable to the original samples. The colour rendition of the pathology samples was accurate. The radiologist and pathologist commented that they were no less confident in making diagnoses from the PC screen than if they were diagnosing the original samples.

It is important to note that the digital enhancements used to aid making a diagnosis cannot create detail but merely highlight it. Some knowledge of digital image properties may be required to effectively apply these techniques and ensure the correct enhancement is applied for each situation.

The ECG in electronic form produced by the CT200 displayed several advantages over the hardcopy ECGs in the telemedicine environment. The most important was the transportability of the data without any loss in quality, as opposed to photocopying and scanning of the hardcopy ECGs. The electronic data file was much smaller in size than the scanned ECG files and could be viewed directly from the computer screen with superior definition and clarity. Emerging software technologies can make a diagnosis from the electronic ECGs which is not possible with a scanned ECG.

The quality of the audio in the video conferencing scenarios was considered excellent. The video quality was considered good and improved with additional network bandwidth. Overall, video conferencing was well accepted by the medical staff and found to be a valuable tool.

7.3 System Usability

The medical staff found the system easy to use with minimal training, and often worked unsupervised. Their reaction to the system was positive and they appeared impressed with the technology and what it had to offer. They were comfortable in diagnosing directly from the computer screen and participating in video conferences. However, some special training was required for an understanding of the properties of digital images and the use of image enhancement techniques.

To derive the maximum benefit from the telemedicine system the technology needed to be supported by doctrine and organisational structure. This was not the case with the demonstration system of the RIMPAC '96 trial. Some procedural changes were made to normal staff routine, such as regularly checking for email, in order to accommodate the system but general accessibility and use of the system was limited. To increase the benefit gained from telemedicine, organisational changes need to be made to ensure a closer match between the way the medical staff work and use of the available telemedicine resources. This may include email exchange to the desktop and easier access to the video conferencing and telemedicine facilities.

The telemedicine system required specialists to attend HMAS Penguin or receive hard copy by mail. This provided a constraint on the responsiveness of the medical support. Connection of the Pilgrim network to emerging civil telemedicine systems, to provide a seamless transfer of information from ship to civilian hospital, was not attempted.

The response times for transferring information across the network were adequate to support the trial. The transfer delay was not too long to hinder the trial activities, and yet was not overly demanding on the underlying network. Table 1 summarises information transfer times. These values were dependent on the portion of Pilgrim bandwidth made available for telemedicine as discussed in Appendix A.

Information Type	Transfer Time
Plain text email, Patient record.	30 seconds
Single (small) x-ray, Multiple pathology slides.	5 minutes
Large multiple x-rays	12 - 15 minutes

Table 1. Typical Information Transfer Times.

7.4 Satellite Performance

The satellite communications links between HMAS Penguin and HMAS Success were of sufficient bandwidth and quality to support the telemedicine applications.

The satellite links were set up for RIMPAC '96, providing coverage of Australia and Hawaii and its territorial waters. Satellite coverage to HMAS Success was not provided for its

whole journey back to Australia. Consequently, telemedical support did not extend to areas where it could have provided the greatest benefit, i.e. where the ship was more than two days transit from port.

There is an inherent transmission delay (the order of 300 milliseconds per hop) in satellite communications which impacts on the quality of real-time interaction over such links. The most significant impact of this delay was seen in the video conferencing as a result of the double satellite hop between HMAS Penguin and HMAS Success. The medical staff quickly adapted to this situation and found the delay acceptable.

8. Conclusions

The telemedicine system was developed with the aim of maximising the use of commercial-off-the-shelf (COTS) technologies and successfully demonstrated their potential in a naval medical environment. Similar functionality to commercial telemedicine systems was provided at reduced cost. The use of commonly available COTS products allowed the system to be rapidly developed, minimised user training and allowed minimal spares to be carried (repair by replacement).

A disadvantage of the COTS products used was that some offered less functionality than the full price commercial alternative. An example being the computer monitors with reduced screen sizes that were used for the trial. These were, however, of sufficient quality, widely available at short notice, and readily met the objectives of the trial.

The trial did not address the Electromagnetic Compatibility Problems (EMC) of the naval environment. However, only minor problems were experienced.

From a technical perspective the trial of telemedical support to a naval ship at sea in peace time was successful, increasing the level of support to the medical staff and enhancing the level of medical care available to the ship's crew. The quality of medical information transmitted from the ship was satisfactory for shore-side diagnosis and it was shown that low cost COTS digital enhancement techniques can assist with analysing medical imagery.

The welfare video conferencing proved successful being well received by participants and significantly boosted morale.

The trial provided valuable data for future requirements of military telemedicine systems. In order to obtain maximum benefit from telemedicine, a system needs to be matched with work procedures and the organisational structure. This was not the case for the initial telemedicine trial.

Currently there are no technical standards for telemedical equipment. However, the use of video conference equipment which supported International Telecommunications Union (ITU) H.261 and World Wide Web technology worked well for this trial and appears to be gaining support in the broader telemedical community.

The communications support provided by the Pilgrim network satisfied the requirements of the trial. However, the coverage (as provided by PANAMSAT-2) did not extend to areas where telemedical support could potentially provide the greatest benefits, such as where the ship was more than two days transit from port (e.g. between Fiji and Hawaii).

The Pilgrim telemedicine network was isolated from civil telemedicine systems so its ability to electronically transfer information with civilian medical facilities was not trialed.

The restricted physical space in the HMAS Success sick bay was a challenge. The equipment may not have fitted into a DDG or FFG sick bay.

9. Recommendations

Future trials should address the feasibility and benefits of:

- development of work procedures to better match telemedical technology,
- online patient record access,
- desktop conferencing and shared whiteboards,
- remote control of the video camera attached to the microscope to permit real-time interactive analysis of pathology slides,
- use of a flash and tripod when photographing patients,
- on-line patient monitoring particularly for intensive care patients,
- interoperability with the civil telemedical infrastructure,
- more standards (i.e. software interfaces) based equipment,
- smaller COTS equipment (e.g. notebook computer & docking station) in ship's sick bay,
- more rack mountable equipment (e.g. x-ray scanner),
- anti-vibration mounting of susceptible equipment (e.g. microscope camera),
- protecting susceptible COTS equipment from ship's electromagnetic interference by shielding, grounding and power supply filtering,
- electronic management of the telemedicine network.

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11. Abbreviations

ADF	Australian Defence Force
ATM	Asynchronous Transfer Mode
C3	Command, Control and Communications
COMMCEN	Communications Centre
COTS	Commercial Off The Shelf
DEFAUSSAT	ADF Satellite Communication System
DEFMIS	Defence Management Information System
DIS	Distributed Interactive Simulation
DPI	Dots Per Inch
DSTO	Defence Science and Technology Organisation
ECG	Electrocardiogram
EMI	Electromagnetic Interference
FDDI	Fibre Distributed Data Interface
FTP	File Transfer Protocol
IP	Internet Protocol
ITU	International Telecommunications Union
JPEG	Joint Photographic Experts Group
LAN	Local Area Network
LZW	Lempel Ziv Walsh
MHQ	Maritime Headquarters
MIME	Multipurpose Internet Mail Extensions
NAVTIMS	Naval Tactical Information System
NPEMS	Naval Personnel Establishment Management System
PANAMSAT	Pan American Satellite System
PC	Personal Computer
POP3	Post Office Protocol 3
POSEIDON	NAVTIMS on a ship
RAID	Redundant Array of Disks
RIMPAC	Rim of the Pacific
SCSI	Small Computer Systems Interface
SMTP	Simple Mail Transfer Protocol
TCP/IP	Transport Control Protocol/Internet Protocol
TIFF	Tagged Image File Format
TWAIN	Toolkit Without an Interesting Name
VCR	Video Cassette Recorder
WFW	Windows for Workgroups
WORM	Write Once Read Many
WWW	World Wide Web

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Appendix A. The Pilgrim Technology Demonstrator

A.1 Overview

The Pilgrim Technology Demonstrator was a network developed to demonstrate the benefits of asynchronous transfer mode (ATM) technology in a military environment and to help define user requirements for C3 systems for the ADF. Pilgrim was deployed to HMAS Success at sea, participating in the RIMPAC '96 exercise, via a commercial C-band satellite.

A.2 Network Structure

For RIMPAC '96 the Pilgrim network consisted of one maritime and four land based nodes interconnected through commercial satellites as depicted in Figure A1. The four land nodes were located at: DSTO in Salisbury, SA; DSTO in Fern Hill Park, Canberra; HMAS Penguin in Balmoral, Sydney; and Maritime Headquarters in Potts Point, Sydney. The maritime node was the supply ship HMAS Success near Hawaii.

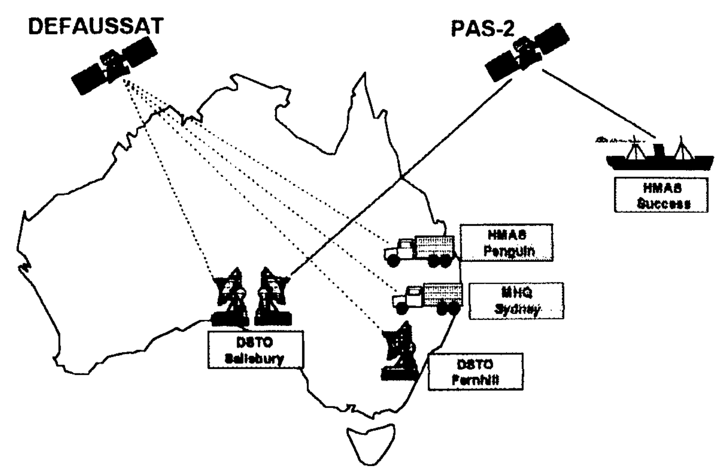

Figure A1: *The Pilgrim Network during RIMPAC '96*

The four land nodes were connected in a star network via 512 kbits/s Ku-band satellite (DEFAUSSAT) links, with DSTO Salisbury at the hub. HMAS Success was connected to DSTO Salisbury, and hence the other nodes, via a commercial C-band satellite (PANAMSAT) using between 200 and 300 kbits/s bandwidth.

At each node an ATM switch integrated the different traffic types (voice, video and data), into a single information stream for transmission across the network. A Sun workstation, connected to both the ATM switch and the local area network (LAN) of each node,

provided a seamless interconnection of the LANs of the five sites as well as a platform to run native ATM applications.

A PictureTel video codec was connected to each ATM switch and a four port video bridge was connected to the ATM switch at DSTO Salisbury. This enabled real-time, multi-site video conferencing across the network and the distribution of live video.

A.3 Pilgrim Applications to/from HMAS Success at Sea

A.3.1 Telemedicine

As described in Section 5 of the body this report.

A.3.2 Remote Restricted High Naval Information Network (RHNIN)

The Pilgrim network was used to investigate the feasibility of online access to the RHNIN from a standalone, shipboard terminal on HMAS Success to support the ship's administration, logistics and personnel management functions. The RHNIN connection would facilitate access to a number of RHNIN information services such as LOTUS Notes interpersonal messaging and server database, Defence Management Information System (DEFMIS) and Naval Personnel Establishment Management System (NPEMS).

The Pilgrim backbone provided the seamless interconnection of a LAN segment on HMAS Success to the Naval Information Network at Maritime Headquarters. No independent end-to-end encryption was required at Restricted level due to the bulk ship-to-shore link encryption.

A.3.3 SECRET Message System Interconnect (NAVTIMS-POSEIDON Link)

The Pilgrim network was used to trial a 9.6 kbits/s data link between the Naval Tactical Information Management System (NAVTIMS) (shore) and POSEIDON (ship) messaging systems. Security mandated that the connection had to be end-to-end super-encrypted. In the absence of ATM cell based encryptors, super-encryption was carried out by standard Type I devices and passed over the ATM network as an externally clocked circuit emulation (AAL1).

A.3.4 DIS Trial

The Pilgrim network was used to trial a distributed interactive simulation (DIS) over satellite to HMAS Success. Servers were set up at Maritime Headquarters and HMAS Success and DIS data was distributed using IP over ATM. A recording of the traffic flow was made for the DIS data for later analysis.

A.3.5 Briefings and Demonstrations

The Pilgrim network allowed briefings and presentations to be conducted at one node and transmitted across the network to other nodes. These presentations included live video transmissions, video conferencing and PowerPoint slide shows. The DSTO Canberra node was also regularly used for giving real time demonstrations of the telemedicine system to visiting executives.

A.3.6 Web and Voice Services

The Pilgrim network was used to distribute information using World Wide Web (WWW) services. A webserver located at DSTO Salisbury contained up to date information including news headlines, weather maps and forecasts, instruction manuals for the Pilgrim equipment, and photographs from the RIMPAC '96 exercise. This information was visible from all nodes of the network using any standard commercial web browser (such as Netscape Navigator).

A voice service was offered through digital phones connected to the Sun workstations in the network. Each node including HMAS Success had the ability to call the others and conduct real-time phone conversations.

A.4 Telemedicine Bandwidth Allocation

The satellite link to HMAS Success was a limiting factor in the Pilgrim network. This link operated at between 200 and 300 kbits/s total bandwidth, depending on environmental conditions. Approximately 10% of the bandwidth was consumed by ATM overheads and 128 kbits/s was allocated for video conferencing. Typically 50 kbits/s peak bandwidth was available for shared LAN traffic, which included all telemedicine information exchange. The remaining bandwidth was used by other Pilgrim services.

The times to transfer varying types of telemedical information from HMAS Success to HMAS Penguin using the Netscape email software were previously detailed in Table 1 (main body of report). These times were considered very acceptable by the medical staff and would be reduced for direct file transfers rather than by attaching the file to an email.

Faster transfer times could have been achieved by reducing the 128 kbits/s bandwidth of video conferencing and re-allocating this bandwidth to LAN traffic. If the video conferencing was not needed then shutting it down would free up its entire bandwidth for re-allocation to other network services.

Alternatively, the information in Table 1 could be used to set a minimum required bandwidth given a defined transfer time. For example, if 30 minutes was the maximum allowable transfer time then a bandwidth of at least 25 kbits/s would be required for LAN traffic.

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Appendix B. Telemedicine Hardware

B.1 Objectives

Hardware selection was based on maximising the leverage from COTS technologies (i.e. economy, standardised interfaces, ease of use, etc.) allowing for rapid development of the telemedicine system.

B.2 Hardware Issues

COTS products provided a familiar interface to users and thus did not cloud the telemedicine concept with technical complexity. COTS products were also supportable, standards based (SCSI, RS232, TCP/IP, etc.), field tested, and integrated well to form a useable system. They were both cost and time effective in rapidly developing a demonstration system. A flexible hardware design was desirable to allow the system to evolve during the trial to meet the changing needs of the user.

Various issues impacting the hardware to be used in the telemedicine system are outlined below. All these considerations had the potential to critically impact on the success of the telemedicine trial. Also, some minor problems with the telemedicine equipment occurred during the trial and are discussed in the following sections.

B.2.1 Personal Computer

A personal computer (PC) was selected as a platform for the telemedicine system due to its availability, minimal cost and standardisation. It provided interfaces based on commercial standards, such as SCSI and RS232, for easy connection to the scanner, digital camera and ECG machine. It also supported the Microsoft Windows operating system providing a familiar interface so minimising user training.

Originally a notebook computer was planned for the telemedicine node on HMAS Success due to space considerations and the ease of removing the laptop from the system to do analysis "off-line". However, several technical difficulties were encountered with the notebook that made it unsuitable: its network and SCSI interface cards were non-trivial to configure and consume more base memory than a PC; and the quality of its external video driver was unsatisfactory for viewing medical imagery. A solution would be a notebook computer with a docking station. The docking station could provide slots for conventional network and SCSI interface cards as well as support better quality video drivers. This option was not pursued due to time and cost.

B.2.2 Computer Monitor

Because diagnosis of the x-rays and pathology slides occurred directly from the PC monitor it was important that the image quality on the screen was excellent. For this reason Sony

Trinitron monitors were purchased, providing a large dynamic range of brightness and contrast which was important for viewing and diagnosing x-rays. They also supported the high resolutions (at least 1024 by 768 pixels) and colour depths demanded by telemedicine images. Image interpretation was also improved by dimming the room lights.

When the computer monitor was installed in the sick bay of HMAS Success the quality of the displayed image was degraded due to the increased electromagnetic interference (EMI) in this environment. No immediate solution was found and appropriate grounding, shielding and power supply filtering need to be addressed. For example, a low-grade TEMPEST protected COTS monitor should be immune to EMI.

The ability to simultaneously observe multiple views of the same x-ray sample was considered important and may require multiple monitors. When using a single monitor more than one image could be simultaneously displayed in PhotoShop, but due to the size of x-ray images one image was usually partially hidden by another.

B.2.3 Digital Camera

The Kodak DCS200 35mm digital camera captured high resolution (1524 x 1012 pixels) colour images directly to a hard disk within the camera. These images could then be transferred to the PC for storage or for attachment to an email for transmission to a remote node. This camera provided the excellent image quality necessary for photographing pathology slides and skin disorders, for example. Its interface to the PC was an industry standard SCSI bus.

A problem with photographing the skin of patients was poor lighting which may be improved with the use of a ring flash. Some form of stand or tripod to support the camera is needed to remove blurring from the images due to unsteady hands. A better understanding of the digital camera and its lenses would also help improve image quality.

B.2.4 X-Ray Scanner

The Raven RSU1 x-ray scanner produced a digital x-ray image from traditional film x-rays. This scanner had a higher optical density, faster scan rate, greater bit depth and larger scan area than conventional scanners. It produced files in industry standard lossless tagged image file format (TIFF) which were transferred to the PC via a SCSI bus.

The x-ray scanner presented numerous problems with reliability and in integrating it with the other equipment. It was not possible to locate the scanner near the PC because of its physical form and so the 2 metre limit on a SCSI cable could not be met. A special 6 metre SCSI cable was tested but failed to work with this scanner. A rack mountable scanner, or one with a better physical form factor, would be an advantage for installation in the confinement of a naval ship.

The resolution and bit depth of the scan produced compared favourably with existing telemedicine systems. Unfortunately the Raven scanner did introduce artefacts (ie scan lines) into the images, which may have been related to this particular brand of scanner.

B.2.5 Microscope

The Olympus microscope provided adaptors for fitting a still image and video cameras. This allowed the Kodak DCS200 digital camera to capture images of the pathology slides being examined.

The microscope proved to be of excellent quality and well suited to telemedicine but requires some fine tuning to take full benefit of its features. When the ship's motors were running the resulting vibrations in the sickbay caused some of the digital images taken through the microscope to become blurred. To overcome this some from of anti-vibration mounting will be required.

The field of view seen through the digital camera, when attached to the microscope, was far less than that seen through the eyepiece resulting in a much smaller area of the slide being captured. This was due to the physical properties of the digital camera (which modifies its effective focal length) and could be improved with some adjustments to the lenses used in the camera adaptor for the microscope.

Being able to remotely alter the position of the slide under the microscope in real time was considered a desirable feature, but was not available in this trial. A way to achieve this would be to attach a video camera to the microscope, adjust the view through the microscope interactively using the video conference, and then use the video codec's "snapshot" feature to capture a still of the slide. The quality of the transmitted image for diagnostic purposes was not determined. The adaptor for attaching a video camera to the microscope was however not compatible with the video cameras used in the telemedicine system during the trial, and this feature was not achieved. There are merits in achieving this and some solution to this problem should be found.

B.2.6 ECG Machine

The CT-200 electrocardiograph (ECG) machine provided a standard serial interface (RS232) for transferring an ECG reading to the PC in a digital format. A software interface was provided for controlling the ECG machine and saving readings to file for later transfer across the telemedicine network. The ECG machine was also portable, running on batteries if needed, and so readings could be taken at the patient's location rather than trying to move the patient to the ship's sickbay. This ECG machine also functioned well in the 'noisy' electromagnetic environment found on HMAS Success.

B.2.7 PictureTel Codecs

PictureTel codecs were used for video conferencing because of the high quality of their video and audio as well as their number of video inputs and outputs. They provided up to five simultaneous video inputs allowing connection of a VCR and several auxiliary cameras

(located on the flight deck and in the cargo control room of HMAS Success). All video inputs of the codec were able to be captured and transferred to the remote nodes as a higher resolution snapshot. An additional output of the codec was used for connection to the ship's video system for distribution of relayed television broadcasts.

The TV broadcast relayed to HMAS Success through the video codecs was of poorer quality than the ship's crew were accustomed to but it was considered of sufficient quality to be a worthwhile service. Even broadcasts with a lot of motion in the picture, such as football matches, were considered acceptable by the crew. Increasing the codec bandwidth from 128 Kbits/s to 256 Kbits/s significantly improved the quality of the picture.

PictureTel codecs are standards based which will facilitate connection to commercial telemedicine facilities, many of which also use PictureTel.

B.2.8 Medical-in-Confidence Switch

The Pilgrim network not only provided medical video conferencing between the sickbay of HMAS Success and the naval hospital at HMAS Penguin, but also provided communications between all the land based nodes and relayed non-medical video to the HMAS Success video system and bridge. To protect medically sensitive information a switch was installed in the sick bay of HMAS Success which prevented video conferencing information being transmitted elsewhere on the ship. In addition, during medical video conferencing the system could also be switched to a point-to-point link between HMAS Success and HMAS Penguin instead of the usual non-medical multipoint conference between all nodes.

B.2.9 Equipment Space on HMAS Success

There was limited space available in the sick bay on HMAS Success for installing the telemedicine equipment. A standard 19 inch rack was used for stacking the equipment in a manageable location while consuming minimal space. Given that similar space problems exist in most military environments preference should be for equipment in a rack mountable form. The 19 inch rack also provided a means for securing the equipment so that it would not move during transit. Special arrangements had to be made for tying down and securing the equipment which was not located within the rack.

The SCSI bus which connected the scanners and digital camera to the PC limited the distance by which these devices could be separated. The maximum length for an entire SCSI chain is 6 metres, with any single link being 2 metres. For devices to be permanently connected to the SCSI bus they must therefore be located in close proximity of the PC. On HMAS Success the Raven X-ray scanner presented a problem in that this physical limit could not be met. The solution was to store the scanner in a secure position while in transit and then move it closer to the PC for connection to the SCSI bus when a scan had to be made. While this situation was satisfactory for the trial it would definitely not be for an operational system.

B.2.10 Sanitised Medical Environment

Installation of the equipment in a surgical area should not compromise maintaining a sterile environment. On HMAS Success it was desirable to mount the 19 inch rack clear of the sick bay floor to prevent dust accumulation and also that all exposed metal surfaces should be either painted or made of stainless steel. These requirements were waived during the trial due to the temporary nature of the installation but any long term plans for telemedicine on HMAS Success would need to address these issues in detail.

B.3 Improvements

Resolution of the issues identified above will improve system performance. Other improvements to the trial system could be made in the area of increased equipment reliability. This will come with a better understanding of the environment in which the system operates and the selection of quality equipment. By addressing the issues of size, location and ergonomics of the equipment improvements could be made in the layout of the hardware installation in the telemedicine sites. This would improve system ease of use, better integration into the daily activities of the medical staff, and greater access to other services provided by the network.

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Appendix C. Telemedicine Software

C.1 Objectives

The selection of software was based on achieving rapid integration and prototyping of the capabilities necessary for an adaptable and functional military system that can adequately demonstrate telemedicine concepts.

C.2 Software Issues

Various issues impacting the software to be used in the telemedicine system are outlined below. They include compatibility between software packages and the interfaces controlling the system hardware. Some comments regarding the performance of the software are also given.

C.2.1 Operating System

Microsoft Windows provided a familiar and easy to use interface for the medical staff (many of whom would use Microsoft Office), plus an extensive range of Windows-based COTS software was available which was important in rapid prototyping of the telemedicine system. Windows for Workgroups (WFW) 3.11 was selected as the most appropriate Windows product.

WFW supported various network functions which increased the effectiveness of the trial: shared networked printers for local and remote printing, and peer-to-peer file transfer for sharing information without a fileserver.

WFW supported TWAIN (Toolkit Without An Interesting Name) standard drivers upon which the MicroTek scanner and digital camera interfaces were based. Also, applications such as Adobe PhotoShop were available for WFW with TWAIN drivers. The same support was not available for the Windows 95 operating system at the time of the trial and this was a critical factor in selecting WFW.

C.2.2 Adobe PhotoShop

Adobe PhotoShop provided a platform for viewing digital images in a wide variety of formats, including TIFF and JPEG, and contained a suite of powerful image enhancement tools. PhotoShop also supported TWAIN compliant software to provide the necessary interfaces to the scanner and digital camera.

Image enhancement techniques were essential to fully utilise the digital x-ray imagery and so increase the confidence in a diagnosis. It allowed the radiologist to modify the characteristics of an image in a region of interest to highlight relevant detail. Enhancements included contrast variation and edge sharpening.

PhotoShop was one of the most suitable COTS applications available for this purpose.

C.2.3 Netscape Navigator

Netscape Navigator (Version 2.01) provided: a principal front end to the telemedicine software; a simple email capability; and an information distribution capability. It allowed tight integration of the viewing applications with the email so that the user could view and analyse a variety of information without needing to know which application was required for the task. Netscape Navigator was also a valuable tool for distributing information throughout the Pilgrim network based on world wide web technologies.

Netscape is a widely used application and its familiarity helped make the medical staff feel at ease when using the system. Netscape was not a complete front end to the telemedicine software since Windows File Manager and Program Manager were also required.

The ability to provide a single interface to much of the software used (email, PhotoShop, LView, ECG software, Web pages) was significant in making the system easy to use. The email also proved an indispensable tool for general communications between all nodes of the Pilgrim network. It was used for more than just telemedicine, including transferring software and collaborative problem solving.

Netscape email was based on the standard Simple Mail Transfer Protocol (SMTP) and Post Office Protocol 3 (POP3) and thus was easily integrated into the telemedicine network. This mail system provided a simple and efficient means to transfer large images across the network for remote diagnosis. The user simply identified a designated image file as an attachment to an email and transmitted it to the desired location.

Some bugs were found in this version of Netscape but these were able to be worked around. They included problems in software stability and in creating new mail folders.

C.2.4 X-Ray Scanner Interface

The software interface for the Raven x-ray scanner did not use TWAIN compliant drivers but was controlled through a separate application. This application did not integrate with Adobe PhotoShop but only saved the scanned image to file from where it would then have to be viewed and diagnosed. This interface was poor and not up to the standard of other windows applications. The software was also incompatible with the other hardware requiring the x-ray scanner to be the only device on the SCSI bus when operated.

C.2.5 ECG Software

The ECG software was simple to use and provide a high quality graphical output of the ECG. The file format used to save the digital information was a proprietary format as no known standard existed at the time of the trial. This will impede exchange of information with other telemedicine systems. The operation of the ECG and the software was such that it could display 'live' ECG readings on the machine or record a 7 second snapshot (either to

paper or through the PC software). A desirable feature would be to have the software capable of displaying 'live' readings on the PC, from where they could be distributed across the network.

C.3 Improvements

Greater use of software and hardware interfaces based on commercial standards would allow a more tightly integrated system to be developed. Proprietary formats for interfaces and files, such as for the x-ray scanner and ECG machine, added to the complexity of the system for no additional benefit.

Other applications, such as desktop conferencing and shared whiteboards would be a valuable addition to the telemedicine software and should be considered for inclusion in future trials.

As applications become ATM aware they will be able to take advantage of quality of services guarantees available in an ATM network. This will also lead to more efficient use of bandwidth and reduction in information transfer times.

A shortfall of the telemedicine software was the inability to monitor, configure and control a remote telemedicine PC. This is a problem associated with PC operating systems and may be resolved by future operating system technologies. Management of the telemedicine network was not addressed during the trial and the addition of some sort of management system should be considered.

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Appendix D. Telemedicine Trial Procedures

D.1 Medical Control Samples

The x-ray samples were digitised on board HMAS Success using the Raven Radiographic Scanning Unit which was specifically acquired for this purpose. Each x-ray was scanned using the enhanced mode of the scanner at the preset resolution of 146 dpi. The resulting image was loaded into PhotoShop, where it was cropped if required, and saved in a lossless tagged image file format (TIFF) with LZW compression. All the x-rays from a particular sample were attached to a single Netscape email, with no clinical history or symptomatic information, and sent over the network to HMAS Penguin.

A radiologist at HMAS Penguin diagnosed the x-rays directly from the PC screen and the results were recorded for comparison with the reference diagnoses. All x-rays relating to a particular sample were viewed with PhotoShop with various image enhancements to aid diagnosis.

The pathology slides were photographed in the sick bay of HMAS Success using the digital camera attached to the microscope. Several images, of varying magnifications and regions, were taken for each pathology sample. The images from the digital camera were loaded into PhotoShop on the PC, scaled to an appropriate size, and saved in a compressed JPEG image format. The level of compression selected was for a High quality image, where the available levels were Low, Medium, High and Maximum. All the images relating to a particular sample were attached to a single email and sent over the network to HMAS Penguin. Some symptomatic information was provided in the email for each sample.

A pathologist at HMAS Penguin diagnosed the samples directly from the PC screen and the results were recorded for comparison with the reference diagnoses. All images relating to a particular sample were viewed simultaneously with PhotoShop with various image enhancements to aid diagnosis.

Most of the control ECGs were in a hardcopy form, being photocopies of printed ECG readings made prior to HMAS Success sailing. One control ECG was in digital form as recorded with the CT200 ECG machine. The hardcopy ECGs were scanned (at 200 dpi) using the MicroTek flatbed scanner connected to the PC, and saved to a file in a compressed JPEG image format. The level of compression selected was for a High quality image. The digital ECG from the CT200 was downloaded to a file on the PC and saved in a proprietary ECG file format. Each ECG file was attached to an email, no symptomatic information was provided, and sent to HMAS Penguin.

At HMAS Penguin all the ECGs were printed on the HP LaserJet 4 with a selected print resolution of 300 dpi. They were then diagnosed by a cardiologist.

For all control samples the results from the trials were compared to the reference diagnoses. Comments made by the diagnosticians on the usability of the telemedicine system and quality of its images were also noted.

D.2 Medical Scenarios

Each of the planned scenarios was addressed in turn. All the relevant x-rays, pathology samples and ECGs for a given scenario were digitised on board HMAS Success using the same procedures as for the control samples described above. A Netscape email was composed and the digitised data files attached. In addition, the relevant patient history, current symptomatic information, preliminary diagnosis, plus advice or service requested by the ship's doctor were attached. The email was then sent to HMAS Penguin for action. The source of the image data for each of the scenarios was taken from either the control samples or from additional x-rays brought on board HMAS Success specifically for the scenarios.

At HMAS Penguin, staff would regularly check the email to see if any requests for medical advice, i.e. a scenario, had arrived. If so, the medical staff would read it and initiate action ranging from making a diagnosis to coordinating a video conference between HMAS Success and HMAS Penguin. The results of the action were compiled into a reply email and returned to HMAS Success. From these scenarios an assessment of the benefits of the telemedicine system could be made.

D.3 Real Medical Situations

Real medical situations which presented on HMAS Success during the trial were handled in the same way as the scenarios except that real patients were present. The situations which presented during the trial were dermatological ailments in which the digital camera was used to photograph the affected area. To initiate communication when action was required a direct phone link (part of the Pilgrim system) was provided between the Naval Hospital at HMAS Penguin and the COMMCEN of HMAS Success. This phone was also available on a 24 hour basis to cope with emergencies.

The staff at HMAS Penguin took the appropriate action to address each real medical situation. This included phoning a dermatologist and requesting their attendance at HMAS Penguin to undertake diagnosis and liaise directly with the medical staff of HMAS Success. For these real situations there was ongoing correspondence between the staff at the two telemedicine nodes.

Appendix E. Filmless Radiology at New Children's Hospital

This appendix provides salient details of the filmless radiology system at the New Children's Hospital, Westmead, NSW.

Digitising

X-ray image size:	10 inches x 17 inches (full chest)
Quantisation:	12 bit greyscale
Resolution:	2K x 2K pixel set. (2K/10" = 200 dpi max.)
Compression:	Lossless LZW, 2.5:1 compression ratio
Resulting Image File Size:	Approx. 8 - 10 Mbyte

Viewing

Screen Size:	21 inch
Type:	High luminance, black and white
Resolution:	1280 x 1024 pixels, screen 1024 x 1024 pixels, image viewing area
Greyscale:	8 bits

Network

Transport Protocol:	TCP/IP
Type:	Ethernet (10 Mbits/sec) LAN FDDI (100 Mbits/sec) backbone ISDN (128 kbits/s) dial-up access

Archival

Short Term:	210 Gbyte total Made up of 9 Gbyte disks in 5 RAID disk arrays 5 months storage
Long Term:	5 Tbytes total Made up of 4 Gbyte WORM optical disks 5 years storage

Point of Contact

Mr. Paul Haigh, Siemens Medical Systems

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G.S. Harrison

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19. ABSTRACT

An experimental Commercial Off The Shelf (COTS) based telemedicine system was developed in less than three months and trialed on HMAS Success during RIMPAC '96. It provided similar functionality to commercial telemedicine systems, but at reduced cost. It increased both the level of support to ship's medical staff and medical care to ship's crew, but to derive maximum benefit the technology needs to be supported by doctrine and organisation structure.

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